Appendix B: Fish associated with live and dead *Montastrea* and ellkhorn coral heads.

Coral type	Live Montastrea										Dead Montastrea										Live Elkhorn										Dead Elkhorn									
Numer	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
Microspathodon chrysurus			1			2	1	1		1	1							1					2				1	1		1			1				1	1			1
(yellowtail damselfish)			[1]	[1]		[1]					[2]		[1]										[2]	[1]									1	1							
Stegastes fuscus			2		2			1					2	1	1		3		1				1	3									3	2							
(dusky damselfish)			[2]										[1]		[1]	[2]	[1]						[1]	[3]									2	1							
S. partitus					1	1		1	2																															
(bicolor damselfish)					[2]	[1]						[1]																												
S. variabilis	1	1	1		1	1	2	1		1	2		3		1			1	2	3																				
(cocoa damselfish)	[1]		[1]		[1]	[2]									[1]																									
S. planifrons	1						1	2	2	1							1	1									1	2	2											
(threespot damselfish)	[1]		[1]			[1]					[2]	[2]																												
Holocentrus adscensionis												1																												
(squirrelfish)												[1]																												
Neoniphon marianus																																								
(longjaw squirrelfish)																																								
Surgocentron coruscus																																								
(reef squirrelfish)							1																																	
Myripristis jacobus											2																													
(blackbar soldierfish)											[2]																													
Plectrypops retrospinus																	1																							
(cardinal soldierfish)																																								
Apogon binotatus						1																																		
(barred cardinalfish)																																								
Pempheris schomburgki																																								
(glassy sweeper)																																								
Fistularia tabacaria																																								
(trumpetfish)																																								
Cephalopholis fulvus					1	1							1																											
(coney)																																								
C. cruentata					1																																			
(grasby)																																								
Serranus tigrinus				1			1			2	1		1		1																									
(harlequin bass)				[1]																																				
Rypticus saponaceus						1																																		
(greater soapfish)																																								
Amblycirrhitus pinos	1			1	2																					1	1	1	1											
(redspotted hawkfish)	[1]		[1]		[1]								[1]																											
Blenniidae or Clinidae																	1																							
fam. sp. (unidentified)						[1]							[1]																											
Ophioblennius atlanticus									1									1	1																					
(redlip blenny)		2																																						
Malacoctenus triangulatus		[1]																																						
(saddled blenny)	1				1								1																											
Acanthemblemaria spinosa	[1]		[1]										[1]																											
(spinyhead blenny)											1																													
A. aspera												[1]																												
(roughhead blenny)												1																												

PATTERNS AND FUNCTIONS OF FOLLOWING BEHAVIOR IN THE SPOTTED GOATFISH (*PSEUDUPENEUS MACULATUS*)

NICOLE D. POULIOT AND JENNIFER L. MITCHELL

Abstract. (NDP) Juvenile spotted goatfish (*Pseudupeneus maculatus*) have been seen as solitary individuals in the shallow back reef, but are more often observed within heterospecific schools or following a particular leader fish. W e observed the following behavior of spotted goatfish in an attempt to determine its pattern and function. All goatfish followed predominantly bluehead wrasse, princess parrotfish, and slippery dicks of approximately the same size as themselves. Large juveniles spent significantly more time alone than smaller individuals possibly because of the different ontogenetic diet requirements or the different size-related predation risks of spotted goatfish. Goatfish spent a significant;y greater proportion of its solitary time foraging when compared to the proportion of its following time spent foraging. Thus, individuals appear to forage more efficiently outside of the group indicating that the following behavior is not for feeding facilitation, but rather for cover or predator protection.

INTRODUCTION (NDP)

The spotted goatfish, *Pseudupeneus maculatus*, is commonly found in the shallow back reef waters of Discovery Bay, Jamaica. Individuals are generally characterized by three dark spots stretching laterally across their white bodies and by two barbels under their chin. These barbels are used to dig in sand and rubble for small crustaceans, fish eggs, and polychaetes, which are the main components of a spotted goatfish diet (Randall 1967). Spotted goatfish juveniles have been seen as solitary individuals, but are more often observed within heterospecific schools or following one particular individual. Unable to find sufficient literature on the solitary and schooling behavior of these fish, we set out to examine the pattern and function of spotted goatfish following behavior.

Some following behavior has been studied in a few species of the goatfish family (Mullidae). According to Uiblein (1991), small Red Sea goatfish (*Parupeneus forsskali*) schooled significantly more in both conspecific and heterospecific groups than large Red Sea goatfish. He attributed these differences to size-related changes in predation risk. Similarly, Gunderson (1992) observed that all juvenile spotted goatfish in the fore reef of Discovery Bay, Jamaica exhibited heterospecific schooling often following one specific member of the school. In contrast, all adults were found as solitary individuals. He, therefore, proposed that schooling served to either decrease predation risk or increase foraging efficiency as heterospecifics might stir up benthic organisms. Lastly, Losey (1978) wrote that many *Parupeneus* spp. of goatfish associate with Labrids similar to their own size, following and feeding closely beside them. As Labrids have been shown to follow mixed species schools for either the cover or flushing of prey organisms that they offer, Losey suggests that the goatfish may follow the Labrids to obtain the same benefits.

During our preliminary observations, we noticed many aspects of goatfish following behavior, some of which supported these past findings and others which contradicted them. We did see small juvenile spotted goatfish, that, at some point, did not appear to be associated with any school or leader, in direct contradiction to Gunderson (1992). Also, those goatfish in schools did not appear to always follow one specific individual within the group. Lastly, we never saw any heterospecific stirring up sediment that might facilitate spotted goatfish feeding. In fact, our

observations suggest that the goatfish spend a greater proportion of solitary time foraging compared to the proportion of their following time that is spent foraging.

We therefore proposed and tested three predictions. First, because predation risk generally decreases with increasing body size, large spotted goatfish should spend more time alone than smaller individuals. Second, spotted goatfish will follow heterospecifics similar in size to themselves. Lastly the proportion of solitary time that a goatfish spends foraging should be greater than the proportion of following time that it spends foraging. These are based on our observations and our belief that following does not facilitate feeding.

METHODS (NDP)

We watched 28 juvenile spotted goatfish and their behavior on the back reef of Discovery Bay Marine Laboratory, Jamaica. Observations were made by two observers while snorkeling from 02-08 March, 1995, between 0800-1100 and 1400-1700. Upon encountering a goatfish, we would first measure its standard length. We then conducted a ten minute trial recording the species of each fish that the goatfish followed (hereto referred to as the leader) and the leader's estimated length. We also recorded the number of times that the focal fish changed leaders and how many times the goatfish was associated with an entire school rather than one particular individual. Additionally, we recorded the total time spent alone and the total time spent following. (The term following includes being associated with an either an entire school or following one particular individual.)

In addition, for 14 of the 28 goatfish we recorded the total time spent foraging while alone and the total time spent foraging while following. We then calculated the proportion of solitary time spent foraging and the proportion of following time spent foraging using the ratio:

Total solitary (or following) foraging time
Total solitary (or following) time

We pooled all data because there was no apparent difference between behaviors observed in the morning or in the afternoon. We then compared spotted goatfish length with the total amount of time spent alone and goatfish standard length with the mean length of the leader. Lastly we performed a Wilcoxon matched-pairs signed-rank test to compare the proportion of solitary time spent foraging to the proportion of following time spent foraging.

RESULTS (JLM)

In this study, we quantified how often spotted goatfish change leaders and what species these leaders include. On average, goatfish changed leaders 10.5 times during a 10 minute time period. We found that the bluehead wrasse (*Thalassoma bifasciatum*) was the species most often followed by goatfish (Fig. 1). The princess parrotfish (*Scarus taeniopterus*) and the slippery dick (*Halichoeres bivittatus*) accounted for 19%

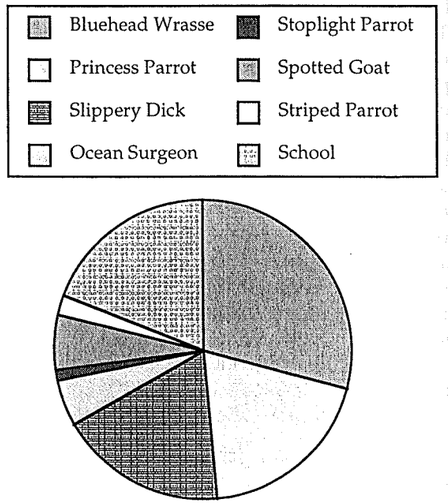

FIG 1: Proportions of species followed by *P. maculatus* (N=28). "School" indicates that goatfish were associated with a school without following one specific individual.

and 18% of leaders, respectively. All other observed leading species including ocean surgeonfish (*Acanthurus bahianus*), other spotted goatfish (*Pseudupeneus maculatus*), striped parrotfish (*Scarus iserti*), and stoplight parrotfish (*Sparisoma viride*) accounted for a small proportion of leaders (<6% each). The leaders were all juveniles and occurred within schools or alone. We also found goatfish juveniles often associated with a school without following one specific individual (19% of leader changes).

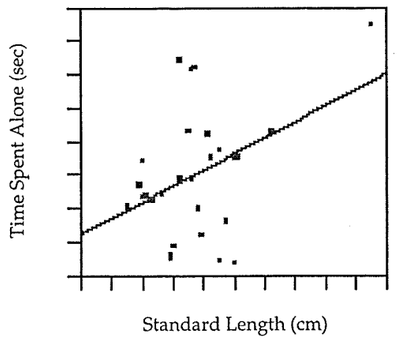

FIG 2: Regression of time spent alone with *P. maculatus* standard length during 10 minute observation periods (N=28, r^2=0.166, P=0.031).

There was a significant positive correlation between goatfish standard length and time spent alone (df=1,26, r^2=0.166, P=0.031, Fig. 2). There was also a significant positive correlation between goatfish standard length and leader standard length (df=1,26, r^2=0.575, P=0.000, Fig. 3).

Finally, we found that goatfish spent a significantly greater proportion of their time feeding when they were alone than when they were with a leader (Z=-2.794, df=13, P=0.005, Fig. 4). On average, when goatfish were alone they spent 44% of their time feeding, whereas they spent only 21% of their time feeding when following a leader fish.

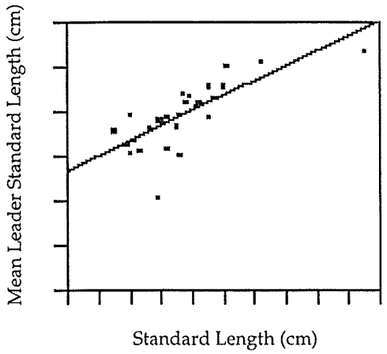

FIG 3: Regression of mean leader standard length with *P. maculatus* standard length during 10 minute observation periods (N=28, r^2=0.575, P=0.000).

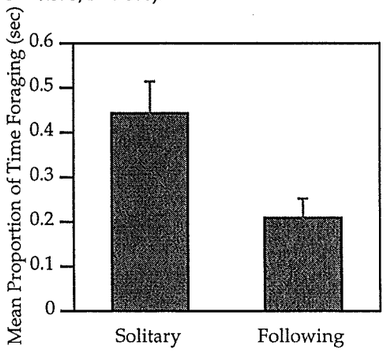

FIG 4: Mean proportions (± SE) of time spent foraging by *P. maculatus* while solitary and while following a leader or associating with a school (N=14, Z=-2.794, P=0.005).

DISCUSSION (JLM)

Our results indicate that juvenile spotted goatfish tend to follow juvenile wrasses (Labridae) more than other fishes. Forty-seven percent of leader fishes were either bluehead wrasses or slippery dicks. We suspect that goatfish may prefer following labrids because of similarities in body morphologies or diet between them. Labrids were occasionally observed foraging in the same microhabitats as goatfish. Thus, in following a wrasse rather than an herbivorous parrotfish, for example, a goatfish may be able to forage

in sand while still gaining protection from being partnered with a leader.

The only other species which was found to be commonly followed was the princess parrotfish. Our observations indicated that this is the most numerous species in the back reef, and therefore goatfish encounter rates with princess parrotfish are likely to be higher than with any other species. It is probable that goatfish frequently follow princess parrotfish simply because they are most likely to encounter it first whenever they are alone and looking for a leader.

We also found that juvenile goatfish often do not necessarily follow one specific leader fish, but may simply remain in close association with an entire school. Although we made no quantifications, our observations suggested that it was the larger juveniles who most often displayed this behavior. We believe this fits in with our hypothesis that larger juveniles spend more time alone than small juveniles. There may be a continuum in which very young fish remain close to a leader fish most of the time, and with age this behavior becomes less important. Thus, as they grow older they begin to only associate with schools rather than individuals and spend increasing amounts of time foraging alone. Finally, once they become adults, the majority of their time is spent foraging alone.

This prediction that goatfish juveniles spend increasing amounts of time alone as they grow older and larger was supported by our data. The finding that juveniles do spend a fair proportion of time alone contradicts observations made by Gunderson in 1992 that juveniles always occur in schools. Our finding may have differed because Gunderson's study was conducted in the forereef, where predators may be more abundant. On the other hand, our results are consistent with Gunderson's finding that adults forage over a wider area due to different dietary needs. As fish become larger and foraging over broader areas becomes important, it is logical that they may need to disassociate from leader fishes to be able to do this.

Although we did find a significant correlation between goatfish size and time spent alone, size only explained 17% of the variation in time alone. A major problem with this part of our study was the limited size range of goatfish found in the back reef. The large majority of juveniles we encountered were 7-8 cm standard length. Only 2 juveniles in our sample were greater than 10 cm standard length. If we had a greater and more evenly distributed size range of goatfish, then the extent to which time spent alone and goatfish size would be more clear.

Our second prediction that leader size would be correlated with goatfish size was strongly supported. We believe this may occur because similarly sized fish are able to swim at similar rates. Additionally, we speculate that staying with a fish of similar size may aid in decreasing apparency to predators.

Finally, our hypothesis that juvenile goatfish exhibit following behavior for predator protection rather than for feeding facilitation by sediment mixing was supported. When goatfish are alone, we found they spend a significantly greater proportion of their time feeding than they do when they are associated with another fish. If a leader did facilitate feeding for goatfish, then the opposite result would have been expected. We believe that goatfish were actually better able to feed when they were alone because they could then choose the most preferred substrate. When following another fish, it appears that goatfish feeding is limited by where the leader may go. Often, leaders prefer areas with algal cover, rather than the bare sand which goatfish juveniles seem to prefer.

Interesting topics for future study would include a quantification of time spent by various species of leaders in substrate appropriate for goatfish feeding. If there are differences, it would also be useful to test whether goatfish actually prefer following those species which spend more time in or near sandy substrate.

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APPENDIX (NDP)

In addition to our study of the pattern and purpose of following behavior, we also hoped to observe and perhaps explain the purpose of color changes of spotted goatfish individuals as well. While we did see many color changes in the field, we were unable to test any predictions concerning its function. However, observationally we believe that color changes are used primarily for crypticity.

Of the 11 color changes from white to red that we noted, two occurred when another spotted goatfish suddenly entered the area. Therefore, it is possible that the change also serves a communication purpose. The other nine red changes took place when the goatfish was over coral covered with red or brown algae. This usually resulted when the goatfish followed its leader or the school over the reddish substrate. Unable to feed there, the goatfish appeared to turn red and blend in with the surrounding area until the leader or school moved on.

In addition, we also observed seven color changes in which the goatfish turned a light green. All of these occurred when the fish was over or within a Thalassia bed. Therefore, because 16 of the 18 color changes we observed resulted in the goatfish blending in with its background, we believe that its main function is crypticity.